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# Impact assessment of the hydroelectric power plant on lake ecosystems (using the example of Lake Oświn)

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**Abstract:** The paper discusses the anticipated impact of the planned hydroelectric power plant on the ecosystem of the "Siedem Wysp" ("Seven Islands") Bird Reserve. To assess the impact, the MapInfo system was used, aided by the Vertical Mapper application.

**Key words:** protection of water environment.

## Introduction

Owing to its unique landscape, characterised by considerable height differences and large lakes interconnected with watercourses often having water-gap sections, the north-eastern part of Poland offers many possibilities for use in power generation. However, this type of commercial activity stands frequently in conflict with the need to protect water and wetland ecosystems.

The paper aims to highlight the impact of the operation of a small hydroelectric power plant on the surrounding natural environment within the meaning of the Ordinance of the Minister for Environmental Protection, Natural Resources and Forestry of 13 May 1995 on identifying investment projects harmful to the environment and human health and environmental impact assessments.

The planned hydroelectric power plant is to be erected in the vicinity of the "Siedem Wysp" Bird Reserve on the incomplete and inoperative Masurian Canal, about five kilometres from its outflow point from Lake Mamry. The plant's planned annual output is 3500÷4000 MWh.

## Research area

The "Siedem Wysp" Bird Reserve comprises, first and foremost, Lake Oświn, sometimes referred to as the Lake of Seven Islands (Jezioro Siedmiu Wysp"), and its adjoining areas. It is situated in the northernmost tip of Poland (Fig. 1), near the state border with the Kaliningrad District, in the north-eastern part of the Sępopol Plain, which is a mesoregion of the Old Prussian (Staropruska) Upland, a part of the Eastern Baltic Coastline (Kondracki, 1999).

In terms of relief, the Sępopol Plain is an extensive basin reaching up to 80–100 metres a.s.l. along the outer edges and lowering down to 40–50 metres towards the centre. This region borders on the Mrągowo Lake District in the south, and the Great Masurian Lakeland and the Węgorapy Region in the east, from which it is separated by a range of morainal hills.

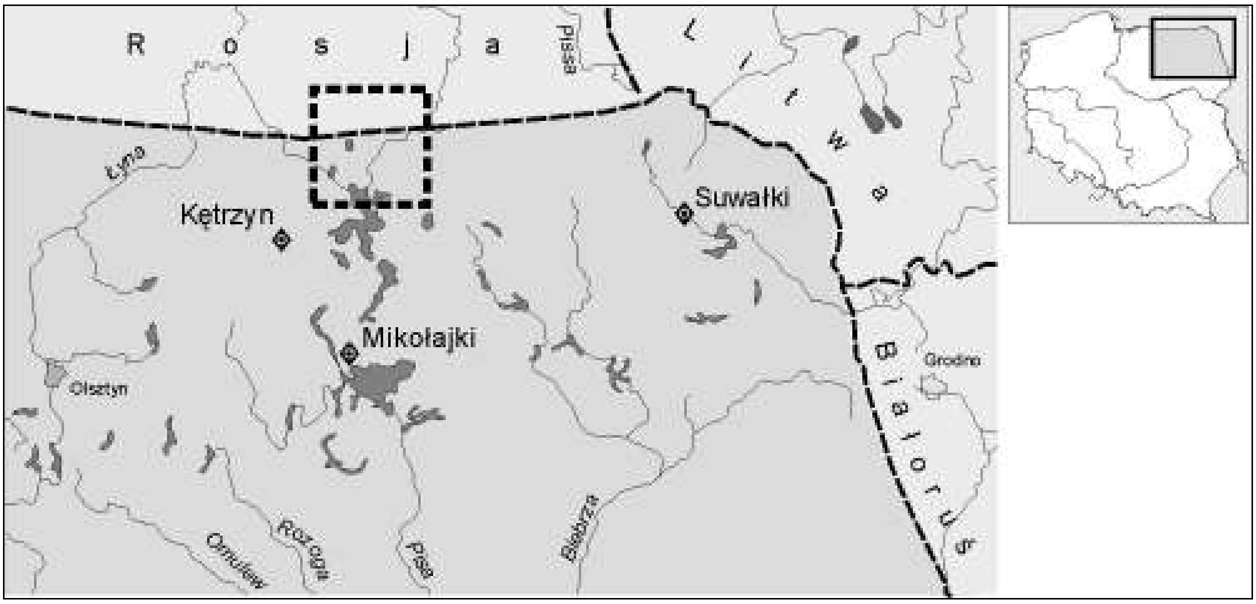


Fig. 1. Situational map of the area under research

Due to its natural assets and beautiful scenery, since 1949 Lake Oświn has enjoyed the status of a nature reserve for the protection of waterfowl and marshfowl, as well as plant communities. In 1983, Lake Oświn with the adjoining areas was included in the list of areas protected under the Ramsar Convention (PAO 02.03.3.09). This is a breeding area for such species as the great crested grebe (*Podpiceps cristatus),* mute swan (*Cygnus olor),* black-nested grebe (*Podiceps nigricollis),* bittern (*Botaurus stellaris)*, grey lag goose (*Anser anser),* gadwall (*Anas strepera)*, corn crake (*Crex crex)*, crane (*Grus)*, black stork (*Ciconia nigra)*, lesser spotted eagle (*Aquila pomarina*), cormorant (*Phahalcrocorax*). In the migration periods (spring and autumn) about 300 goose, mainly white-fronted goose (*Anser albifrons)* and bean goose (*Anser fabalis*) flock here. It is also a popular stopover point for cranes, sometimes gathering as many as 200 birds (Dyrcz, 1989; Wesołowski, Winiecki, 1988).

The waters of Lake Oświn fill an extensive, dead ice melt-out depression, although the lake itself has many features of an ice-marginal lake, in the west resting against a frontal moraine. This is a groundwater lake, the existence of which depends on the stability of the first freatic water-bearing level. The lake's surface area is approximately 3.416 $km^2$, two times less than in 1954, when it reached 6.379 $km^2$. At the time, the lake gathered 7043.5 thousand $m^3$ of water, and had the maximum depth of 3.5 metre and the average depth of 1.1 metre (Kondracki, 1960).

The Lake Oświn catchment covers an area of 144.9 $km^2$ (Fig. 2) and is built from the ground moraine boulder clay formed during the Pomeranian phase of the Baltic glaciation, reaching several dozen metres deep. In the substratum structure of the vicinity of Lake Oświn, solid deposits reach 40–60 metres deep (Bajkiewicz-Grabowska, 1999), while gravel and stone deposits occur locally, in places marking the front of the receding continental glacier. In shallow undrained hollows formed following the melting of the dead ice cakes, peat can be found.

Oświn is a flow-through lake; alimented by many watercourses (Fig. 2), the major of which include:

- The Rawda river, draining the southern part of the Lake Oświn catchment, including lakes: Rydzówka, Węgielsztyńskie oraz Surwile; the Rawda river basin occupies an area of 75.5 $km^2$ (51.6% of the Lake Oświn catchment),
- The Ruda river, also known as the Świnka, draining the eastern, lakeless part of the Lake Oświn catchment; its basin covers 48.0 $km^2$ (33.1% of the Lake Oświn catchment).

In addition to the above rivers, Lake Oświn aliments nine other watercourses, which as a rule drain wetland basins with surface areas ranging from 0.24 to 2.23 $km^2$ (Bajkiewicz-Grabowska, 1999). Nearly the entire Lake Oświn catchment is covered by a thick agricultural drainage network, the water from which is primarily received by the Rawda and the Ruda.

The runoff from the lake is effected through the Oświnka, flowing into the Ilma, a right tributary of the Lyna, on the other side of the border. It is regulated by a weir, situated on the river near its outflow point from the lake. The weir reduces the runoff from the lake to 1.6 $m^3/s$.

None of the rivers alimenting Lake Oświn has hydrometric monitoring, just as the Oświnka, which flows from the lake. In the 1980s and 1990s, several hydrometric measurements were taken in the Lake Oświn catchment. On their basis, some conclusions may be drawn on the runoff conditions in the catchment and the average annual river alimentation to the lake; also, the annual runoff may be assessed (Bajkiewicz-Grabowska, 1999). It can be said, therefore, that the rivers annually discharge into Lake Oświn on average 19.5 million $m^3$ of water, of which:

— The Ruda aliments 9.1 million $m^3$, i.e. approximately 47% of the aggregate annual river inflow into the lake;
— The Rawda aliments 7.5 million $m^3$, i.e. approximately 39% of the aggregate annual river inflow into the lake.

On average, 19.9 million $m^3$ water runs off from the lake through the Oświnka.

In the Lake Oświn catchment basin, the upper section of the Masurian Canal is located (Fig. 2). Hydrographically, the Canal is an independent unit; its drainage basin is contained by the narrow strip between the embankments, while the intersecting streams flow through the Canal via siphons.

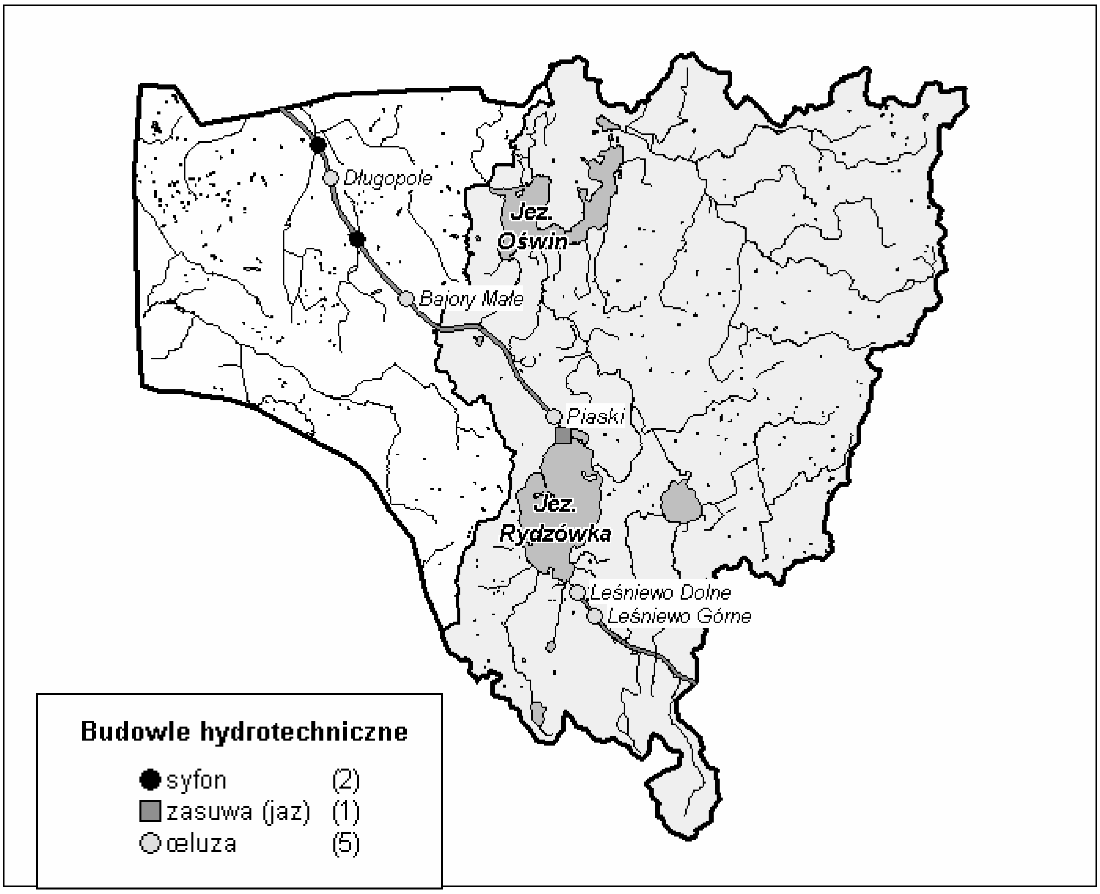


Fig. 2. Lake Oświn catchment

The idea behind the Masurian Canal was to connect the Great Masurian Lakes with the Vistula Lagoon (and further on, with the Lyna and the Pregola). According to the project, nine sluices were planned, and the difference in the canal levels was to reach 111.2 metres (!) on a 51-

kilometre section. The construction of the canal was started in 1911 and interrupted by the outbreak of World War I in 1914. The works were not resumed until 1934 and were interrupted again in 1941. All the excavations, dykes and most of hydrotechnical facilities were completed by the time of the outbreak of World War II. After 1945, about 21 kilometres of the canal remained within the Polish borders, but the construction works were never finalised.

The Masurian Canal is an earth canal, with a width of about 24 metres at the water-table level and about 15 metres at the bottom, and a depth of about 3 metres In its largee part, the Canal runs between two embankments.

The Canal's section situated in Poland runs from Lake Mamry through Lake Rydzówka north-west towards the state border (Fig. 2). Along this section of a 20.4 km length, five sluices were built to level the differences of 61.5 metres (at Leśniewo Górne, Leśniewo Dolne – above Lake Rydzówka and at Piaski, Bajory Małe and Długopole), of which only one (Piaski) is operational. In Kamień, above the Leśniewo Górne sluice, a double cofferdam welling up the water from Lake Mamry was constructed; this section of the Canal is permanently filled with water. This is the watershed between the Lyna nad the Wegorapa.

Along the Canal's section running from Lake Mamry to Lake Rydzówka, the difference in the water levels is approximately 32.5 metres, and about 29 metres from Lake Rydzówka to the state border.

In normal conditions, the alimentation of the Masurian Canal with the water from Lake Rydzówka is practically nonexistent; only in high water periods the excess water in the lake is discharged through the Piaski sluice into the Canal. After about 3.8 kilometres some of this water is discharged, through a spillway (a monk with a gate valve and a siphon under the canal), via a natural watercourse (Fig. 2) to Lake Oświn, and some, by surface overflow in the cofferdam, aliments the lower section of the Canal, running towards the state border with the Kaliningrad District.

## The design assumptions of the Leśniewo power plant

In order to make use of the differences in the levels of the Masurian Canal along its section running from Lake Mamry to Lake Rydzówka, reaching about 32.5 metres, Leśniewo was proposed as a location for a hydroelectric power plant. The water would flow gravitationally into the Masurian Canal from Lake Mamry to the Leśniewo (Górne) I sluice at 2 $m^3/s$, and then, in a pressure pipeline, to the power plant located at the existing structure of the Leśniewo (Dolne) II sluice. When passing through the turbine, water would be directed through the lower section of the Canal to Lake Rydzówka, from which it would flow through the Piaski sluice to the further section of the Masurian Canal, from where it would be discharged, by an outlet, into a watercourse flowing into Lake Oświn. Therefore the lake would receive additional water at a speed of 2 $m^3/s$, which would significantly affect the circulation of the water in the lake. With increased alimentation and an unchanged runoff, the reservoir retention would be considerably higher. In effect, the surface area of Lake Oświn would grow as a result of flooding the adjoining marshes and meadows, which are protected by law.

## Method for assessing the impact of the Leśniewo power plant on the Lake Oświn ecosystem

In order to assess the impact of the planned hydroelectric plant in Leśniewo on the condition of the natural environment in the Lake Oświn catchment, the MapInfo software supporting the Vertical Mapper application was used. Using this software, a numeric grid of the model of the area was created, based on the isohypses and spot heights obtained in the vectorisation process from the topographic map (scale 1:25 000). This involved changing the isohypses (linear entities) into points of a specific height. The points obtained from the isohypses were connected with spot heights obtained during the vectorisation and shown in one table, on the basis of which a numeric model of the Lake Oświn area was developed (Fig. 3). DTM images were obtained using the triangulation method with a "polishing" stage. The adopted resolution of the resulting grid was 20 metres.

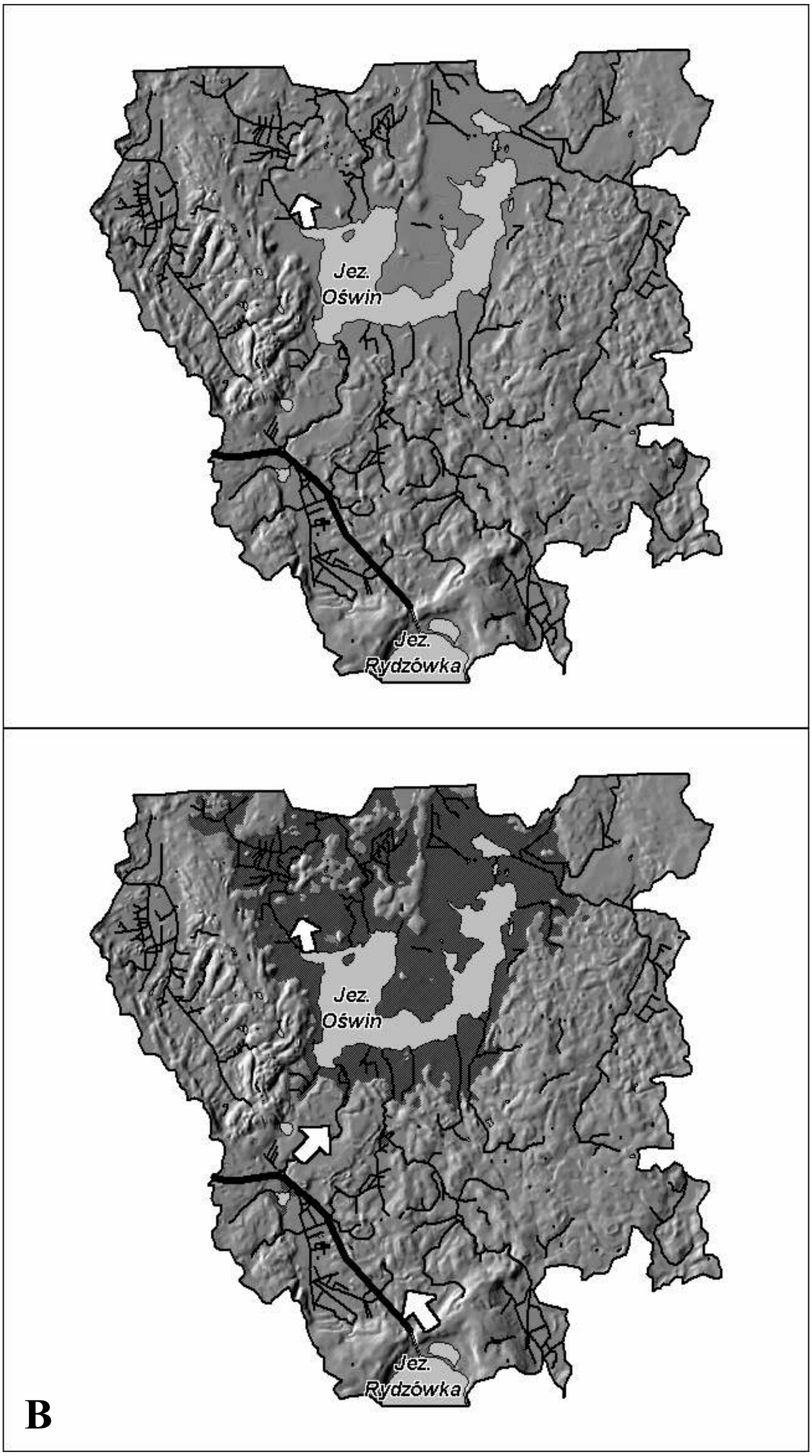


Fig. 3. DTM images of the Lake Oświn area; current (A) and after the launch of the hydroelectric power plant (B)

As the subsequent stage, a network of lines was generated (every one metre), starting from the Lake Oświn water-table (64 metres a.s.l.) up to the level of the planned location of the power plant in Leśniewo (83 metres a.s.l.). The generated lines were transformed into area-type objects (which allows to calculate the flooded or inundated area).

In order to assess the impact of the operation of the planned hydroelectric power plant on the ecosystem of Lake Oświn, the following algorithm was adopted:

1. The annual increase of the volume of water in the lake's ecosystem was determined, depending on the volume of the alimenting water (via watercourses, and water worked by the plant) and water flowing out of the researched area in the Oświnka river.
2. A 20% loss of water was assumed (evaporation, infiltration, leakiness), with small runoff from the lake, at a rate of 1.6 $m^3/s$, which is ensured by the coordinate of the sill damming up water on the Oświnka (65.5 metres a.s.l.).
3. Upon identification of the volume of water which must be "contained" in the melt-out depression occupied by the lake as a result of the operation of the hydroelectric power plant, the coordinate of the inundated area was determined.

## Conclusions

As a result of the operation of the planned hydroelectric power plant in Leśniewo II, 15.5 $km^2$ of the areas surrounding Lake Oświn would be permanently flooded or inundated, which accounts for 11% of the lake's catchment area (Fig. 3). These are swamp ecosystems (mainly Central European alder carr), popular breeding grounds for waterfowl and marshfowl. In view of the above, the planned investment project stands in contradiction with the laws and regulations concerning nature protection and conservation.

This example shows how GIS software can aid the process of assessing the impact of human activity on the natural environment. The function allowing for an easy visualisation of the results obtained can serve as a good argument in the decision-making process in situations where the interests of various stakeholders may be in conflict.

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## Streszczenie


Młodoglacjalny krajobraz Polski Północno-Wschodniej stwarza możliwości wykorzystania energetycznego. Taka działalność gospodarcza pozostaje często w konflikcie z potrzebami ochrony ekosystemów wodnych i bagiennych.

Celem opracowania jest przedstawienie wpływu eksploatacji małej elektrowni wodnej na ekosystem jeziora Oświn (ryc. 1, 2), które ze względu na walory przyrodnicze i krajobrazowe, od 1949 r. jest uznane za rezerwat przyrody chroniący ptactwo wodne i błotne, a także zbiorowiska roślinne, a w 1983 r. wraz z terenami przyległymi zostało objęte szczegółową ochroną na podstawie Konwencji RAMSAR.

Oświn jest jeziorem wytopiskowym o powierzchni około 3,416 $km^2$. Jego zlewnia zajmuje 144,9 $km^2$ (ryc. 2). Oświn jest jeziorem przepływowym; zasilają go liczne cieki (rys. 2), z których najważniejszymi są: Rawda,

odwadniająca południową część zlewni jeziora Oświn, dorzecze Rawdy zajmuje 75,5 $km^2$ (51,6% zlewni jeziora Oświn), oraz Ruda, zwana Świnką, odwadniająca wschodnią, bezjeziorną część zlewni jeziora Oświn; dorzecze Rudej zajmuje 48,0 $km^2$ (33,1% zlewni jeziora Oświn). Poza wymienionymi rzekami jeziora Oświn zasila w wodę jeszcze dziewięć cieków drenujących przeważnie zlewnie bagienne o powierzchni od 0,24 do 2,23 $km^2$ (Bajkiewicz-Grabowska, 1999).

Odpływ z jeziora odbywa się Oświnką, uchodzącą poza granicami kraju do Ilmy, prawego dopływu Łyny. Jest on regulowany przez jaz piętrzący, znajdujący się na tej rzece w pobliżu jej wypływu z jeziora. Jaz ten ogranicza odpływ z jeziora do 1,6 $m^3$/s. W zlewni jeziora Oświn leży górny bieg Kanału Mazurskiego (ryc. 2).

Aby wykorzystać różnicę poziomów Kanału Mazurskiego na odcinku od jeziora Mamry do jeziora Rydzówka wynoszącą około 32,5 m zaproponowano lokalizację elektrowni wodnej w Leśniewie. Woda do Kanału Mazurskiego dopływałaby z jez. Mamry do śluzy Leśniewo II w ilości 2 $m^3$/s. Po przejściu przez turbinę woda byłaby kierowana dolną częścią kanału do jeziora Rydzówka, z którego odpływałaby przez śluzę Piaski ponownie do dalszego odcinka Kanału Mazurskiego, skąd byłaby zrzucana upustem do cieku prowadzącego do jeziora Oświn. Jezioro to otrzymywałoby więc dodatkową porcję wody w ilości 2 $m^3$/s, co zmieniłoby w sposób istotny obieg wody w zbiorniku. Przy zwiększonym zasilaniu jeziora i stałym niezmienionym z niego odpływie wzrosłaby znacznie retencja zbiornikowa, czego efektem byłby wzrost powierzchni jeziora Oświn kosztem zalania przyległych do tego akwenu bagien i łąk, obszarów prawnie chronionych. Powierzchnię zalanego obszaru (ryc. 3) wyznaczono korzystając z oprogramowania MapInfo (Vertical Mapper).

w tym jeziora: Rydzówka, Węgielsztyńskie oraz Surwile;